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Change of Rigidity of Fish Body during Decomposition.

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Formerly, Prof. M. TAUTI, I. HIROSE, and H. WADA⁽¹⁾ stated that the freshness of raw fishes can be judged of the rigidity of their body.

The present report deals with the experiments on the relation between the amount of the decomposition product contained in the muscle of fishes and the rigidity of their bodies, and the influence of the temperature and that of the mechanical shocks on the relation in question.

The writer wishes to express herewith his hearty thanks to Prof. Dr. M. TAUTI for the constant guidance and also to Prof. Dr. T. ÔYA for the valuable advices rendered to him.

I.—Influence of temperature.

Method of experiment. Fishes used for this experiment were 24 carp, 550–680 grams in weight.

Eight carp were put in a thermostat at 9°C., after being killed by cutting the nerve centre.

They were taken out once a day and the rigidity of their body was measured at a point between the lateral line and the dorsal fin.

The method of measurement was the same as that described in the above cited paper.

After the rigidity being measured, one specimen was immediately stripped off the skin and the muscle was chopped. The chopped meat, 50 gr. in weight, was grounded up with quartz-sand and then the ammonia contained in it was estimated by the following method:—

(1) M. TAUTI, I. HIROSE & H. WADA:—A Physical Method of Testing the Freshness of Raw Fishes. J. Imper. Fish. Inst. Vol. XXVI, No. 2, 1931.

The sample was put in a Claisen distilling flask with 150c.c of methyl alcohol and 150c.c of pure water and then 50c.c of 10% potassium oxalate and 50c.c of 15% potassium carbonate were added. Heating the distilling flask on a water bath at 45°C., the vapor was led into a receiver filled with $\frac{1}{10}$ normal sulphuric acid for 30 minutes by an aspirator.

Then, the fluid was titrated with $\frac{1}{10}$ normal sodium hydroxide solution. The amount of ammonia (mg.) was gained by multiplying the titration value by 1.7.

Similar experiments were made at temperatures of 16°C. and 25°C.

Result of experiment. The results of these experiments are given in table 1.

TABLE I.

<i>D</i>	$\Theta=9^{\circ}\text{C}$		$\Theta=16^{\circ}\text{C}$		$\Theta=25^{\circ}\text{C}$	
	<i>R</i>	<i>A</i>	<i>R</i>	<i>A</i>	<i>R</i>	<i>A</i>
0	170	6.1	160	6.9	160	—
0.3	—	—	—	—	190	—
1.0	260	—	240	8.4	210	10.1
1.2	—	—	—	—	180	11.4
2.0	320	7.4	200	9.2	0	70.0
3.0	300	7.2	180	9.4		
4.0	240	9.9	130	28.2		
4.3	—	—	110	39.0		
5.0	200	—	120	45.1		
5.2	—	—	100	50.7		
6.0	180	17.8				
7.0	200	—				
8.0	200	14.6				
9.0	160	28.0				
10.0	110	38.6				
11.0	120	57.3				
12.0	160	60.8				
13.0	100	—				
14.0	100	61.0				

D: Time in days.
 Θ : Temp. of storing.
R: Readings of Freshness-meter.
A: Amount of Ammonia (mg per 100 gr.).
 Gothic figure indicates a putrefied material.

The table shows the following facts:

- (1) The amount of ammonia contained in the fish muscle increases at a gradual increasing rate with the days after killed.
- (2) The rigidity of the fish body has a maximum value in "rigor mortis," but it gradually decreases afterwards.
- (3) The higher the temperature of storing, the higher both the rates of the change of rigidity and of the increase of amount of ammonia.
- (4) When a putrefactive appearance comes out, the rigidity of fish body and the amount of ammonia contained in the muscle have a definite value irrespective of the temperature of storing.

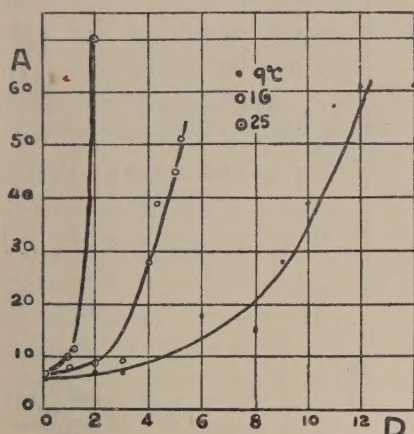


Fig. 1.

Fig. 1 shows the amount of ammonia-content, A , in relation to the days, D , after killed. From Fig. 1, the days needed for taking a given value of ammonia-content are estimated for three cases where the storing temperatures are 9° , 16° and 25°C .

Tab. 2 gives the result of estimation and the ratio of those days at the three temperatures.

From Tab. 2, it will be seen that the ratio is nearly constant such as:

$$D_9 : D_{16} : D_{25} = 2.2 : 1 : 0.38$$

where, D_9 , D_{16} and D_{25} represent time in days at 9° , 16°C , and 25°C respectively. Accordingly in this case, we have $Q_{10} = 3.0$.

Fig. 2 shows the rigidity of fish body and the amount of ammonia-content in relation to D_{16} , the days reduced to 16°C , by using the next formulae:

$$\text{the reduced days} = \frac{1}{2.2} \times \text{the days at } 9^\circ\text{C}.$$

$$\text{the reduced days} = \frac{1}{.38} \times \text{the days at } 25^\circ\text{C}.$$

From this figure, it is clear that the value of rigidity, R , depends only

TABLE II.

A	Time in days.		
	$\Theta=9^{\circ}$	$\Theta=16^{\circ}$	$\Theta=25^{\circ}$
10mg	4.5 1.88	2.4 1	0.8 .33
20	7.8 2.23	3.5 1	1.4 .40
30	9.4 2.24	4.2 1	1.6 .39
40	10.5 2.24	4.7 1	1.8 .39
50	11.5 2.21	5.2 1	1.9 .365
Mean	2.2	1	.38

on the reduced days in just the same way as the amount of ammonia-content does.

Hence we may say that the rigidity of fish body be used as a measure of ammonia-content, taking account of the degree of return.

Discussion: Ammonia is a decomposition product of the muscle protein by the action of enzymes and bacteria.

Assuming that the decomposition by enzymes and bacteria is a monomolecular reaction, the amount of ammonia-content, A , in fish muscle after D days

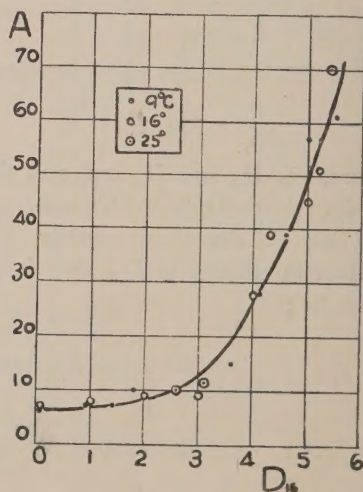
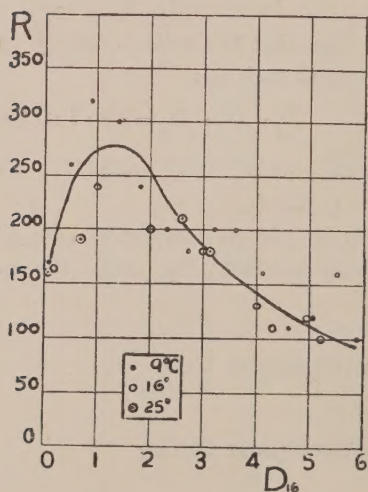


Fig. 2.

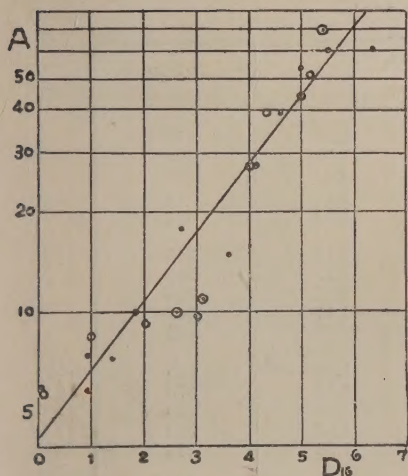


Fig. 3.

Both the actions are due to its decomposition, but the swelling action occurs chiefly at the beginning, while the softening action continues during the whole course of decomposition. Then, after the swelling action was almost completed, the change of the rigidity is due to the softening action alone.

And, as seen in Fig. 2, the rigidity, R , at D days after death may be nearly expressed by

$$R = Se^{K_2 D},$$

and in the present case, $S \approx 350$ and $K_2 = 0.212$ at 16°C .

Granted that the softening action exists from the beginning of decomposition, the relation between D and $Re^{K_2 D}$ May be taken to express the change of rigidity due to the swelling action alone

The relation between D and the calculated values of $Re^{K_2 D}$ given in Tab. 3 is plotted in Fig. 5.

may be approximately expressed by

$$A = A_0 e^{KD},$$

where A_0 represents the initial value of A , and K , the rate of decomposition.

In the present case, we have $A_0 = 4$ and $K = 0.47$ at 16°C . from the graph in Fig. 3. Fig. 3 shows the logarithms of ammonia-content relative to the reduced days.

The change of the rigidity seems mainly to result from two causes, viz., the swelling and softening actions of muscle.

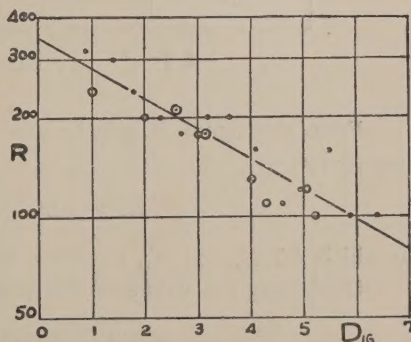


Fig. 4.

TABLE III.

D_{16}	R	$e^{K_2 D}$	$Re^{K_2 D}$
0	170*	1.00	170
0	160†	1.00	160
0	160‡	1.00	160
0.5	260*	1.11	290
0.9	320*	1.20	380
0.8	190‡	1.18	225
1.0	240†	1.27	295
1.4	300*	1.31	395
1.8	240*	1.46	350
2.0	200†	1.52	305
2.3	200*	1.62	325
2.7	210‡	1.76	370
2.7	180*	1.76	320
3.2	200*	1.96	390
3.0	180†	1.88	340
3.3	180‡	1.98	360
3.6	200*	2.13	425
4.1	160*	2.37	380
4.0	130†	2.42	305
4.6	110*	2.64	290
4.3	110†	2.48	275
5.0	120*	2.88	345
5.0	120†	2.88	345
5.5	160*	3.15	500
5.2	100†	3.00	300
5.9	100*	3.45	345
6.4	100*	3.86	386

* $\Theta=9^\circ$ † $\Theta=16^\circ$ ‡ $\Theta=25^\circ$

From this figure, it will be seen that the relation may be nearly expressed by

$$Re^{K_2 D} = R' - (R' - R_0)e^{-K_1 D},$$

in which R' , R_0 and K_1 , are some constants.

Computing the values of the constants, we have

$$R' \doteq 350, R_0 \doteq 160 \text{ and } K_1 = 1.77$$

Hence,

$$R = (350 - 190e^{-1.77D})e^{-.212D}.$$

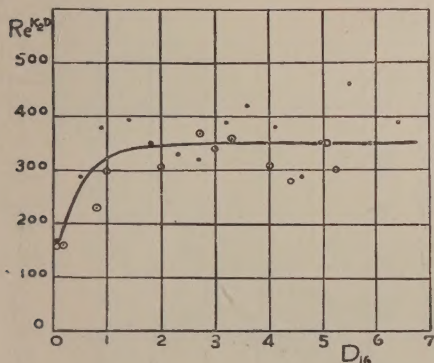


Fig. 5.

Fishes used for this experiment were carp (300~530gr.), flat-fishes (280~500gr.) and porgies (200~330gr.).

Five fishes were put in the box with crushed ice, and then the vacant space of the box was packed with rags.

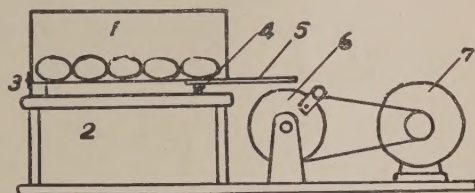
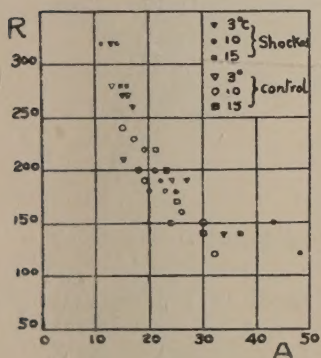


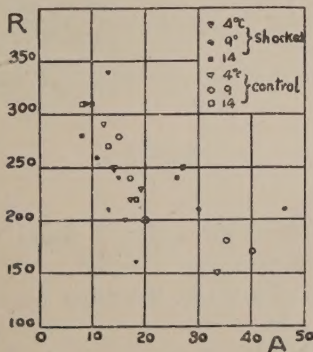
Fig. 6.

1. Fish box 2. Supporting-desk 3. Hinge
4. Spring 5. Iron plate 6. Cam 7. Motor



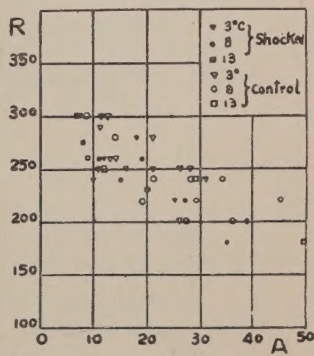
(I)

(I)...Carp



(II)

(II)...Flat-fish



(III)

(III)...Porgy

II.—Influence of mechanical shock.

To apply mechanical shocks repeatedly to fish body, an apparatus as shown in Fig. 6 was used.

One end of fish box, 40^{cm} × 27^{cm} × 16^{cm} in size, is hinged to a supporting-desk and the iron plate, projecting from the other free end, rests on a spring. The plate was set free from the height of 2~3 cm above the resting position repeatedly 66~69 times per minute.

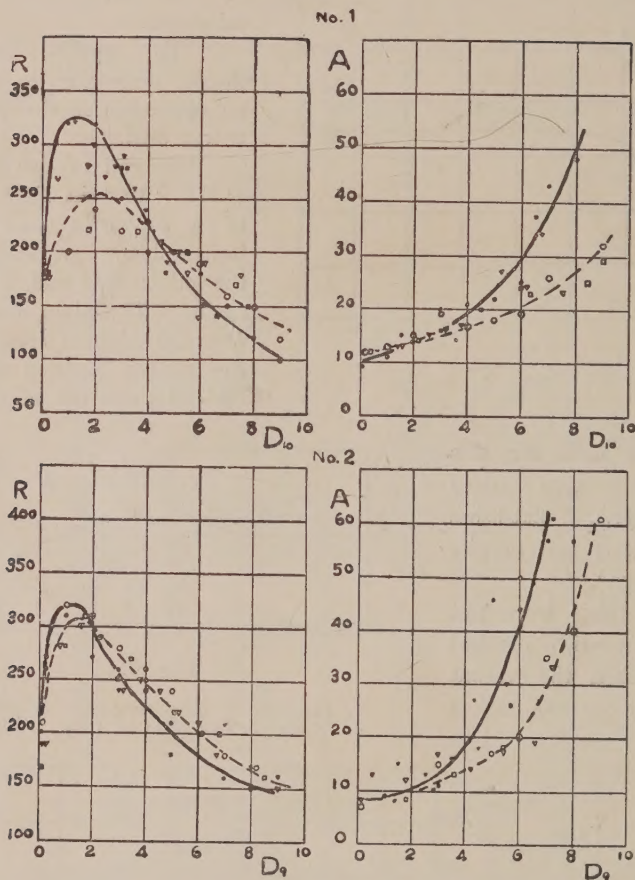


Fig. 8. a.

Mechanical shocks were given for 8 hours continuously. The fishes were interchanged their place every 2 hours.

After the treatment of 8 hours, the fishes were stored in a thermostat with 5 control fishes.

The measurement of the rigidity of their body and the analysis of ammonia in their muscle were made at proper intervals.

Results of the experiments are given in table 4 and Fig. 7.

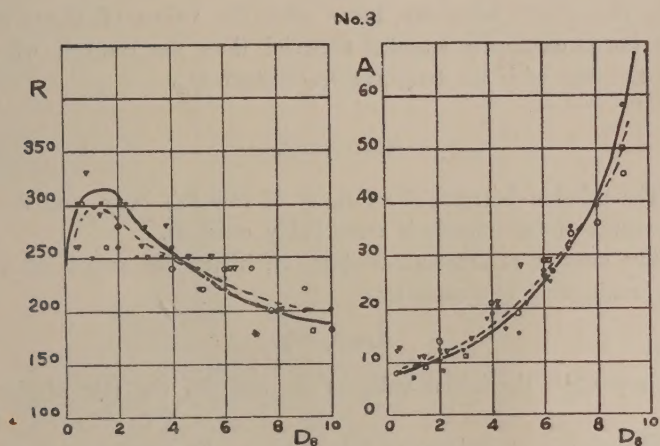


Fig. 8. b.

No. 1...Carp No. 2...Flat-fish No. 3...Porgy ——— shocked.
 ——— control.

In this figure, it is evident that the relation between the rigidity of fish body, R , and the amount of ammonia, A , is not influenced by the mechanical shock applied.

But, change of the rigidity and that of the ammonia-content in relation to time in days differ in the shocked and control material (Fig. 8).

In this figure, we see that both the rigidity and the ammonia-content change more quickly in the agitated material than in the control.

The following table gives the calculated value of K by using the next formula: $A = A_0 e^{KD}$, and the temperature constant obtained from these experiments, etc. (Tab. 5).

TABLE V.

	Carp		Flat-fish		Porgy	
	Shocked	Control	Shocked	Control	Shocked	Control
Temperature... Θ	10°C	10°	9°	9°	8°	8°
Initial value of $A.....A_0$	8.3	11.2	6.6	6.6	7.0	7.4
Rate of decom- position..... K	0.22	0.12	0.29	0.23	0.22	0.22
Temperature constant ... Q_{10}	2.8	3.2	3.0	3.5	5.1	6.2

From the above table we know that the values of K are generally greater in the mechanically agitated material than the control, whereas the reverse is the case with the temperature constant Q_{10} .

Summary.

1. The relation between the rigidity of raw fish body and the decomposition product of fish muscle is remarkably constant.

2. The amount of ammonia-content, A , in the fish muscle after D days can be approximately expressed by

$$A = A_0 e^{KD},$$

where A_0 represents the initial value of A , and K , the rate of decomposition.

3. The change of rigidity of fish body can be expressed by

$$R = [R' - (R' - R_0)e^{-K_1 D}]e^{-K_2 D},$$

where R' , R_0 , K_1 and K_2 are some constants.

4. The decomposition rate of fish muscle and the temperature constant of it tend to vary when the mechanical shocks are given.

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Physical Laboratory, Imp. Fisher. Inst.

TABLE IV.

CARP

D	$\Theta=3^{\circ}\text{C}$				$\Theta=10^{\circ}\text{C}$				$\Theta=15^{\circ}\text{C}$			
	R'	A'	R	A	R'	A'	R	A	R'	A'	R	A
0	180	—	170	—	200	9	180	12	180	—	180	12
1	340	—	270	—	320	11	200	13	280	15	220	14
2			330	—	320	14	240	15	180	20	220	21
3	320	13	280	13	250	20	220	19	150	24	200	23
4					200	21	230	17	140	37	170	25
4.3											150	29
5	290	—	270	—	190	22	200	18				
6	270	15	270	15	180	25	190	19				
7	280	—	240	—	150	43	160	26				
8	290	—	220	—	120	48	150	30				
9	260	17	210	16	100	—	120	32				
10	240	—	200	—								
11	220	—	180	—								
12	190	27	190	24								
13												
14												
15	140	37	180	23								

PORGY

D	$\Theta=3^{\circ}\text{C}$				$\Theta=8^{\circ}\text{C}$				$\Theta=13^{\circ}\text{C}$			
	R'	A'	R	A	R'	A'	R	A	R'	A'	R	A
0												
0.5	340	—	360	—	300	8	300	8	300	7	260	9
1	260	12	260	13					250	8	250	11
2	250	—	330	—	260	12	280	14	230	20	240	29
3			290	11					200	27	180	50
4	250	11			260	19	240	21	180	75	180	89
5	240	10	300	12	240	15	220	19				
6					220	27	240	29				
7	300	12	260	14	180	35	240	34				
8					200	39	200	36				
9	280	18	280	21	200	38	220	45				
10					200	68	180	31				
11	250	16	250	28								
12												
13	250	21	250	26								
14												
15	220	25	240	31								

FLAT-FISH

D	$\Theta=4^{\circ}\text{C}$				$\Theta=9^{\circ}\text{C}$				$\Theta=14^{\circ}\text{C}$			
	R'	A'	R	A	R'	A'	R	A	R'	A'	R	A
0	190	—	190	8	200	—	210	7	160	—	210	—
0.3	280	—	190	—	260	—	250	—	270	—	260	—
1	340	13	280	—	310	9	320	—	280	8	310	8
2	270	—	300	—					310	10	270	13
3	240	15	290	12	260	11	280	15	250	27	220	18
4	200	—	240	—	250	—	260	—	240	26	200	56
5	200	13	250	17	210	46	240	17	180	61	160	71
6	180	—	240	—	200	50	200	20				
7	210	16	220	14	160	57	180	35				
8	170	—	210	—	150	57	170	40				
9	160	18	180	17	150	79	200	61				
10												
11	210	30	230	19								
12	—	44	150	33								

D: Time in Days.

 Θ : Temperature of storing.

R: Rigidity of fish body (control).

R': (Shocked material).

A: Ammonia-content in fish muscle (mg per 100 gr.).

A': Shocked material.

Gothic figure indicates a putrefied material.



Supplying of Intermittent Current to Electric Fish Screen.

Morisaburô TAUTI, *Rigakuhakushi* and

Hideaki YASUDA.

(Received March 1, 1932).

OKADA⁽¹⁾ found that the first-excitation-voltage-gradient* increases as the gradient of voltage gradient along the median line of fish-body decreases when a fish advances into a stronger and stronger field. On leading the movement of fish-group with a set of parallel grating electrodes vertically supported across the stream, he⁽²⁾ showed that the sharp increase of voltage gradient with which the fish-group meet on its way has a great effect. He⁽³⁾ also showed that, when fish-groups are stopped by an electric current with a set of parallel grating electrodes vertically supported across the stream, the neighbourhood of electrodes, especially the part just behind them, is most effective to turn the groups back, while the middle part between the electrodes, especially separated by a large space, is least effective. From these facts we see that, in the case of an alternating current, the change in the voltage gradient with which fish-groups meet in their course has a great effect on stopping them as well as on leading their movement.

Hitherto, the use of an electric current for stopping fish-groups or leading their movement has been attempted only in the fresh water, because on carrying out such an attempt it is needed to consume the electric power in the salt water far more than in the fresh water. McMillian⁽⁴⁾ stated that the highest resistivity river water had a resistivity 880 times that of sea water, while the paralysis-voltage-gradient† of chinook salmon fingerlings in the highest

(1) M. Okada: On the action of electric current on fishes I. Jour. Imper. Fisher. Inst. XXIV, 2 (1929).

* The minimum value of voltage gradient at which fish suddenly felt the current taking a rapid motion.

(2) M. Okada: Note on leading the movement of fish-groups by electric current. Jour. Imper. Fisher. Inst. XXIV, 5 (1929).

(3) M. Okada: On the action of electric current on fishes II. Jour. Imper. Fisher. Inst. XXV, 1 (1929).

(4) F. O. McMillan: Electric fish screen. Bulletin of the Bureau of Fisheries XLIV (1928) and Document No. 1042.

† The minimum value of voltage gradient required to paralyze a fish.

resistivity river water was 4.55 times that in sea water. Accordingly, the consumption of electric power in a screen for stopping them in sea water will be $\frac{880}{(4.55)^2}$ or 43 times that in the highest resistivity river water.

Intermitting the electric current in water may be easily considered to be a means effective to give rise to the change in voltage gradient in electrified region and at the same time to save the consumption of electric energy in the screen. In the present paper, the authors wish to describe the result of experiment done to know the effect of intermission of screen current on stopping fish-groups and on leading their movement.

Model stream used in the experiment was a wooden conduit, 480 cm long and 88 cm broad. Electrodes were (A) 4 thin wires, 300 cm long, in a row put on the bottom and kept at the distance of 0, 11, 22 and 33 cm from one side of the conduit resp., and (B) 3 thin frames, 88 cm long and 10 cm broad, put vertically across the conduit. An alternating current of 50-cycle single phase was supplied and the terminal voltage was adjusted by means of a variable transformer. An apparatus sketched in Fig. 1 was put in the

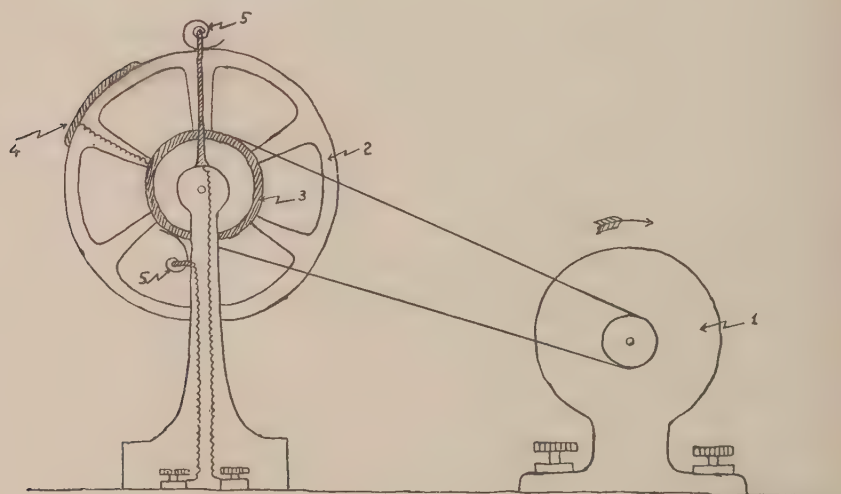


Fig. 1.

- | | | |
|--------------------|--------------------|----------------|
| 1. Electric motor. | 2. Rotating wheel. | 3. Metal ring. |
| 4. Metal plate. | 5. Spring. | |

screen circuit to intermit the current in water. The period of intermission was equal to that of rotation of wheel. The proportion of length of time during which the screen current was made to a period (in the following lines, we call it in the name of "making-factor") was equal to the ratio of the length of portion of wheel covered with a metallic plate to the total length of its circumference. Fishes used in this experiment were gold-fish, 6~8 cm, and carp, 5~8 cm. A number of fishes of each kind were divided in several classes which have some tens of members. Fishes in a class were offered to experiment for about an hour and a half, once a day. When the fishes in conduit started from the space (*P*, Fig. 2) near the downstream end and approached the electrified region, a small part of fishes turned back and went down the stream in front of that region, while fishes of other part entered that region.

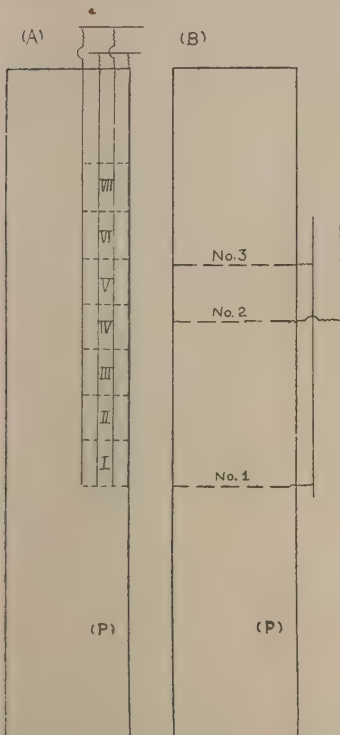


Fig. 2.

But a larger part of the fishes which entered the electrified region, in the case of electrodes (*A*), either turned back and went down the stream or escaped from that region to the mid-stream in the sections of that region (I, II,....., Fig. 2, of equal depth and arranged in order), whereas the rest broke through the whole sections. In the case of electrodes (*B*), a larger part of fishes which entered the electrified region turned back and went down the stream in 2 sections (between the first and second electrodes and between the second and third electrodes). But in some cases of (*B*), the two sections were conventionally divided into sub-sections having a depth of 20 cm. And fish-groups turning back to go down the stream and escaping from the electrified region to the mid-stream and those breaking through the whole sections of that region were counted in the front of that region and in all sections or sub-sections respectively.

The records of observation are given in Tab. I. Tab. II gives the percentage

of fish-groups which broke through the electrified region of various depths and the ratio of fish-groups which turned back and went down the stream in the whole sections to those which escaped from the electrified region to the mid-stream. Tab. III gives the ratio of percentages, calculated from Tab. II, of both cases where the screen current was supplied and not.

In the case of (A), between continuous and intermittent, there is no difference of the ratio of fish-groups which turned back to go down the stream and those which escaped to the mid-stream, as seen in Tab. II. In the case of gold-fish with screen (A), Tab. III shows that, if the same voltage is put on the screen, the stopping effect of an intermittent current is at least equal to a continuous one, when the making-factor is above $\frac{1}{2}$ at the period of intermission of .30 sec., above $\frac{1}{4}$ at .15 sec. and above $\frac{1}{8}$ at .09 sec. This example shows that the making-factor decreases with the period of intermission. On looking through Tab. III, we know that, with the screens (A) and (B) used, the intermittent current, of which the period of intermission and the making-factor are .09 sec. and $\frac{1}{16}$ respectively, has nearly same effect to stop gold-fish and carp used as continuous one has at the same terminal voltage.

When an electric current is supplied in water continuously, as shown by OKADA⁽³⁾ with (B)-type screen and by TAUTI⁽⁵⁾ with (A)-type one, the probability for a fish-group to be prevented in its course by a part of electrified region, r , and the terminal voltage, V , put on the screen follows the following equation:

$$r = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{A \log \frac{V}{V_0}} e^{-\frac{1}{2}x^2} dx, \quad [A, V_0: \text{const.}]$$

But, when the current is supplied intermittently, as seen in Fig. 3, the voltage, V , put on (A)-screen and the probability, r , seem to follow the next equation better than the above one:

$$r = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{V-V_0}{\sigma}} e^{-\frac{1}{2}x^2} dx, \quad [\sigma, V_0: \text{const.}]$$

In Fig. 3, the relation between the value of $\varphi(p)$ which equalizes

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\varphi(p)} e^{-\frac{1}{2}x^2} dx \text{ and the ratio, } p, \text{ of percentages of fish-groups breaking}$$

(5) M. TAUTI: A new form of electric fish screen. This journal XXVII, 1 (1932).

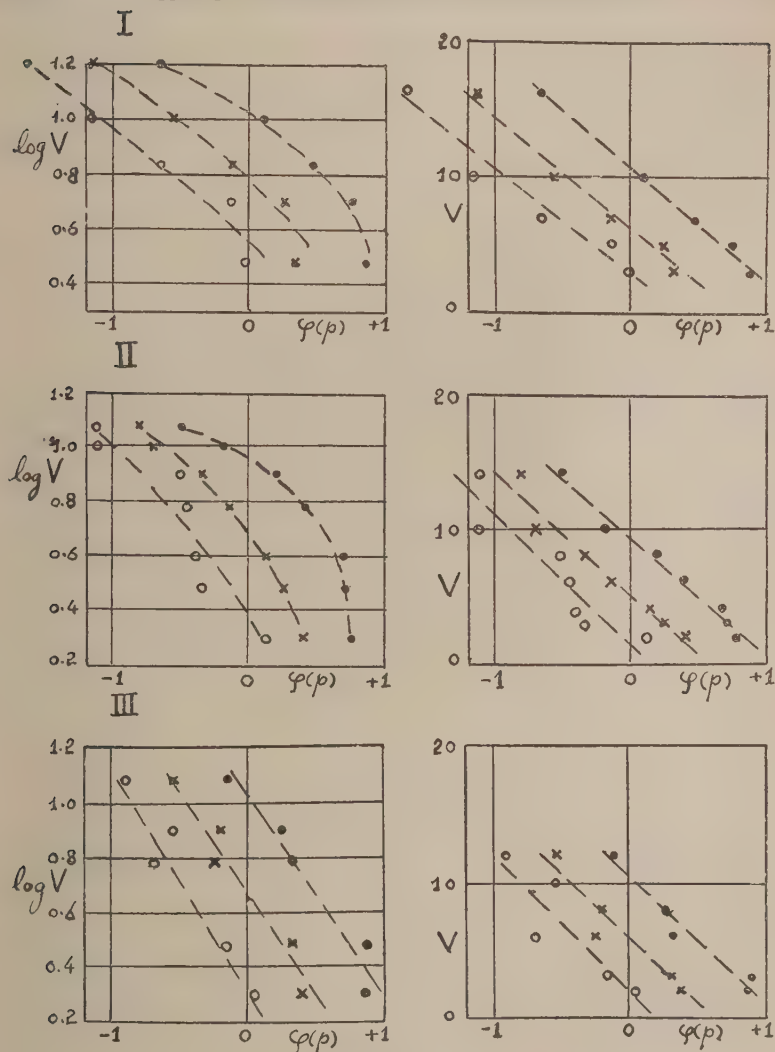


Fig. 3.

Relation between the value of $\varphi(p)$ which equalizes $\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\varphi(p) - \frac{1}{2}x^2} e^{-\frac{1}{2}x^2} dx$ and the ratio, p , of percentages of fish-groups breaking through the electrified region of both cases where the current was supplied and not, and the corresponding value of the terminal voltage, V .

I. Gold-fish, (A)-screen, .09 sec, $\frac{1}{16}$.

II. Carp, (A)-screen, .09 sec, $\frac{1}{16}$.

III. Carp, (A)-screen, continuous.

Depth of electrified region ● ...66, × ...132, ○ ...198 cm.

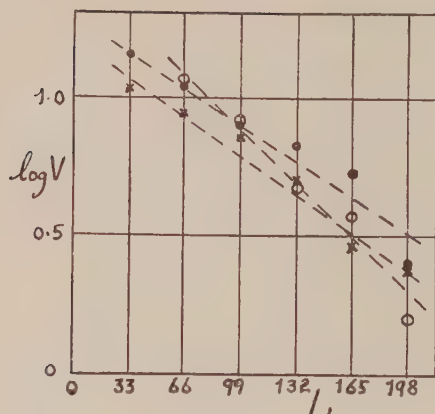


Fig. 4.

Relation between the depth, L cm, of the electrified region and the terminal voltage, V volt, when the percentage of breaking through that region is equal to the half of that in the case where the current is not supplied.

- ...Gold-fish, .09 sec, $\frac{1}{10}$.
- ×...Carp, " " " "
- ... " , continuous.

through the electrified region of both cases where the current was supplied and not, and the corresponding value of the terminal voltage, V , and its logarithm are plotted from Tab. III.

From Tab. III, the terminal voltage is obtained when the percentage of fish-groups baeaking through the electrified region of several depths is equal to the half of that in the case where the current was not supplied. The obtained values are given in Tab. IV. Fig. 4 shows that the relation between that obtained value of the terminal voltage, V , and the corresponding value of the depth of electrified region, L , whether the current is supplied continuously or intermittently, obey the next formula†:

$$\log V = a - b L, \quad [a, b : \text{const.}]$$

TABLE IV.

Terminal voltage when the percentage of breaking through the electrified region of various depths is equal to the half of that in the case where the current is not supplied.

Kind of fish	Period of intermission in sec.	Making-factor	Depth of electrified region in cm					
			33	66	99	132	165	198
Gold-fish	.09	$\frac{1}{10}$	14.2	11.0	8.0	6.6	5.3	2.5
Carp	"	"	10.7	9.0	7.2	5.0	2.8	2.3
"	continuous		—	11.6	8.3	4.8	3.8	1.6

† In the paper previously quoted, TAUTI showed that this formula holds for the case where a continuous current is supplied in (A)-type screen.

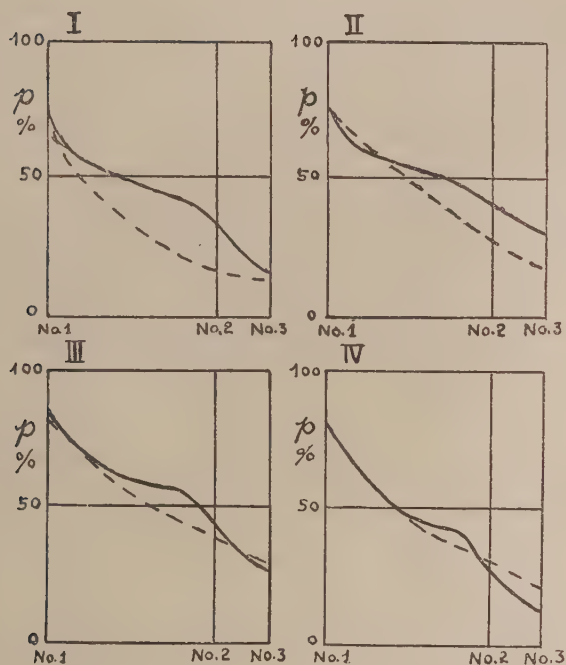


Fig. 5.

The ratio, p , of percentages of fish-groups breaking through the electrified region of both cases where the current is supplied and not, in relation to its depth expressed by the distance from the first electrode. No. 1, No. 2, No. 3.....Position of electrodes.

Full line.....continuous current, broken line.....intermittent current.

I. Gold-fish; terminal voltage: 12 volt. II. Gold-fish; terminal voltage: 8 volt.

III. Carp ; " " : 12 " . IV. Carp ; " : 16 " .

When the current is supplied continuously in (*B*)-type screen, as shown by OKADA⁽³⁾, the neighbourhood of electrodes, especially the part just behind them is most effective to turn the fishes back, while the middle part between two electrodes, especially separated by a large space, is least effective. But, when the current is supplied intermittently, as seen in Fig. 5, the rate at which fish-groups breaking through the electrified region decreases with its depth is nearly constant. Fig. 5 shows the ratio of percentages of fish-groups breaking through the electrified region of both cases where the current is supplied and not, in relation to its depth expressed by the distance from the first electrode.

July, 1931.

Physical Laboratory, Imper. Fisher. Inst.

TABLE I.

Screen: (A). Number of fish-groups which turned back to go down the stream, *t. b.*, and escaped from the electrified region to the mid-stream, *esc.*, in front of that region and in seven sections (Fig. 2, depth of each: 33 cm) and that of those which broke through the whole sections, *b. t.*

Gold-fish 6~8 cm, depth of water: 10~11 cm; temperature of water: 12.3~17.8°C; still water.

Period of intermission in sec.	Making-factor	Terminal voltage in volt	Front	I	II	III	IV	V	VI	VII	Break-ing through	Total
			<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>		
continuous		6.8	4 12	6 6	4 8	8 6	6 6	9 5	7 3	5 4	12	111
.57	$\frac{1}{2}$	"	1 5	3 8	7 9	5 11	6 5	5 6	4 2	6 1	39	123
"	$\frac{1}{4}$	"	1 5	1 7	13 4	8 7	5 3	8 3	5 1	2 0	44	117
continuous		"	2 12	5 7	6 10	11 6	6 4	7 3	6 3	3 3	14	108
.30	$\frac{1}{2}$	"	1 6	11 6	18 5	16 2	8 2	12 2	10 1	5 1	15	121
"	$\frac{1}{4}$	"	3 5	7 8	14 6	13 3	10 1	11 4	5 5	5 0	20	120
"	$\frac{1}{8}$	"	0 8	5 5	6 3	9 4	11 3	5 0	6 1	3 1	38	108
continuous		"	0 7	14 3	12 4	16 1	9 0	9 1	5 0	2 3	14	100
.15	$\frac{1}{2}$	"	1 6	13 5	17 4	12 5	12 2	8 1	5 1	1 0	11	104
"	$\frac{1}{4}$	"	3 10	14 5	24 4	26 1	12 3	4 2	5 0	2 0	8	123
"	$\frac{1}{8}$	"	0 6	8 4	15 3	20 2	11 3	11 0	12 1	6 1	31	134
"	$\frac{1}{16}$	"	0 5	4 7	10 5	14 4	9 4	8 3	7 0	2 1	31	114
continuous		"	3 8	11 9	10 9	12 8	10 4	9 4	10 3	3 3	13	129
.09	$\frac{1}{2}$	"	3 9	7 6	12 4	9 6	5 5	10 4	11 3	3 6	15	118
"	$\frac{1}{4}$	"	3 8	9 10	16 8	11 6	8 4	7 2	6 2	4 2	11	117
"	$\frac{1}{8}$	"	5 13	19 18	24 13	15 13	22 13	18 6	13 5	11 2	30	240
"	$\frac{1}{16}$	"	5 17	18 15	12 16	18 17	16 11	14 10	15 5	8 4	36	237
"	$\frac{1}{32}$	"	2 5	3 7	5 2	6 6	6 4	10 8	8 4	5 3	21	105
"	$\frac{1}{16}$	3.0	0 8	2 6	4 7	3 10	5 7	3 7	3 8	5 4	35	117
"	"	5.0	1 10	5 5	6 4	5 7	6 6	6 6	4 5	2 2	37	117
"	"	10.0	3 28	9 7	8 7	12 6	13 3	9 0	7 5	1 2	8	128
"	"	16.0	1 30	10 21	6 10	4 7	6 2	3 2	1 1	0 1	3	108
"	"	0.0	0 2	1 0	3 0	2 3	3 3	7 3	6 2	8 1	116	160

Carp 5~8 cm, depth of water: 10~13 cm; temperature of water: 16.2~17.8°C; running water.

Period of intermission in sec.	Making-factor	Terminal voltage in volt	Front	I	II	III	IV	V	VI	VII	Break-ing through	Total
			<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>	<i>esc. t. b.</i>		
.09	$\frac{1}{16}$	2.0	1 3	4 5	3 5	1 4	1 4	3 2	2 5	2 7	34	86
"	"	3.0	0 5	4 5	3 9	1 6	2 8	2 10	4 8	1 6	28	102
"	"	4.0	1 5	0 8	2 11	2 9	1 8	3 10	2 8	0 8	24	102
"	"	6.0	2 9	6 6	6 7	3 8	7 5	4 4	0 6	0 3	28	104
"	"	8.0	3 14	6 14	6 13	10 5	6 6	2 4	4 1	2 4	30	130
"	"	10.0	8 16	10 15	7 6	3 8	2 6	4 2	2 4	2 3	8	106
"	"	12.0	2 35	3 21	4 8	2 4	1 5	1 3	0 4	1 3	9	106
continuous		2.0	0 6	1 4	1 8	0 7	3 5	2 9	1 6	1 5	36	95
"	"	3.0	1 5	1 5	3 5	5 4	3 8	4 6	2 10	1 6	32	101
"	"	6.0	8 5	6 9	6 8	6 5	6 6	5 6	3 5	3 3	19	109
"	"	8.0	2 11	2 20	2 5	4 4	2 5	1 9	2 4	2 4	20	99
"	"	12.0	0 19	2 18	2 12	1 10	1 9	1 5	0 5	1 4	13	103
"	"	0.0	0 0	0 0	0 1	0 2	0 1	1 2	2 3	1 1	121	105

Screen: (B). Number of fish-groups which turned back to go down the stream, *t. b.*, in front of the first electrode and in two sections (between the first and second electrodes and between the second and third electrodes), in some cases in eight sub-sections (20 cm deep), and that of those which broke through the third electrode, *b. t.*

Gold-fish 6~8 cm, depth of water: 10~11 cm; temperature of water: 12.3~17.8°C; still water.

Distance between electrodes in cm		Terminal voltage in volt	Period of intermission in sec.	Making-factor	<i>t. b.</i>			<i>b. t.</i>	Total
1st and 3rd	2nd and 3rd				Front of 1st	Between 1st and 2nd	Between 2nd and 3rd		
30cm	10 m	3.0	off screen current		8	9	7	94	118
"	"		continuous		26	29	19	33	107
"	"		.09	$\frac{1}{16}$	29	48	17	23	117
60	20	6.0	off screen current		7	9	8	76	100
"	"		continuous		33	34	24	26	117
"	"		.09	$\frac{1}{16}$	31	51	27	18	127
90	30	9.0	off screen current		7	7	4	100	118
"	"		continuous		26	59	20	18	123
"	"		.09	$\frac{1}{16}$	30	66	14	13	123
120	40	12.0	off screen current		5	5+1+2+1+1+3	4+1	82	105
"	"		continuous		33	19+10+5+5+3+9	11+5	15	115
"	"		.09	$\frac{1}{16}$	32	22+16+8+7+6+6	2+1	11	111
"	"	8.0	continuous		29	21+7+4+3+4+7	7+4	26	112
"	"		.09	$\frac{1}{16}$	34	18+12+7+7+12+5	8+3	17	123

Carp 5~8 cm, depth of water: 11~13 cm; temperature of water: 15.8~17.0°C; running water.

Distance between electrodes in cm		Terminal voltage in volt	Period of intermission in sec.	Making-factor	<i>t. b.</i>			<i>b. t.</i>	Total
1st and 2nd	2nd and 3rd				Front of 1st	Between 1st and 2nd	Between 2nd and 3rd		
120	40	12.0	continuous		14	16+7+8+2+2+14	12+6	27	108
"	"	16.0	"		19	12+13+7+5+1+13	7+7	10	94
"	"	12.0	.09	$\frac{1}{16}$	21	7+12+9+7+4+5	7+7	26	105
"	"	16.0	"		19	16+14+8+4+5+5	8+5	18	108
"	"		off screen current		0	2+0+0+0+0+5	0+2	92	101

TABLE II.

Screen: (A). Percentage of number of fish-groups which broke through the electrified region of various depths to the total number and ratio of number of fish-groups which turned back to go down the stream, *t. b.*, in the whole sections to that of those which escaped from the electrified region to the mid-stream, *esc.*

Gold-fish.

Period of intermission in sec.	Making-factor	Terminal voltage in volt	Percentage of breaking through the electrified region of following depth in cm								<i>t. b.</i> <i>esc.</i>
			0	33	66	99	132	165	198	231	
continuous		6.8	85	74	64	52	41	28	19	11	1.02
.57	$\frac{1}{2}$	"	95	86	73	60	51	42	37	32	1.27
"	$\frac{1}{4}$	"	95	88	76	61	54	44	39	38	.70
continuous		"	87	76	61	45	36	27	18	13	1.04
.30	$\frac{1}{2}$	"	94	80	61	55	38	27	17	13	.31
"	$\frac{1}{4}$	"	93	81	64	51	42	29	21	17	.47
"	$\frac{1}{8}$	"	93	84	75	63	50	45	39	35	.56
continuous		"	93	76	60	43	34	24	19	14	.26
.15	$\frac{1}{2}$	"	93	76	56	39	26	17	12	11	.35
"	$\frac{1}{4}$	"	90	74	51	29	17	12	8	7	.28
"	$\frac{1}{8}$	"	96	86	73	57	46	38	28	23	.24
"	$\frac{1}{16}$	"	95	86	73	57	45	36	30	27	.54
continuous		"	92	76	61	46	35	25	15	10	.71
.09	$\frac{1}{2}$	"	90	79	65	52	44	32	20	13	.72
"	$\frac{1}{4}$	"	86	69	54	39	29	21	15	9	.66
"	$\frac{1}{8}$	"	92	77	62	50	35	25	18	13	.65
"	$\frac{1}{16}$	"	91	77	65	50	39	29	20	15	.90
"	$\frac{1}{32}$	"	94	84	77	66	56	39	28	20	.87
"	$\frac{1}{16}$	3.0	93	86	77	66	56	47	38	30	2.28
"	"	5.0	91	82	74	63	53	43	35	32	1.28
"	"	10.0	76	63	52	38	25	18	9	6	.94
"	"	16.0	71	43	28	18	10	6	4	3	2.38
off screen current			99	98	96	94	89	83	78	72	.47

Carp.

Period of intermission in sec.	Making-factor	Terminal voltage in volt	Percentage of breaking through the electrified region of following depth in cm								<i>t. b.</i> <i>esc.</i>
			0	33	66	99	132	165	198	231	
.09	$\frac{1}{16}$	2.0	95	85	76	70	64	58	50	39	2.0
"	"	3.0	95	86	75	68	58	46	34	27	3.1
"	"	4.0	94	86	74	63	54	41	31	24	6.2
"	"	6.0	89	78	65	55	43	36	30	27	1.5
"	"	8.0	87	72	57	45	36	32	28	23	1.3
"	"	10.0	77	54	42	31	24	18	12	8	1.5
"	"	12.0	65	42	31	25	20	16	12	8	4.0
continuous		2.0	94	89	79	72	63	52	44	38	4.9
"	"	3.0	94	88	80	71	61	51	39	32	2.3
"	"	6.0	88	74	62	51	40	30	23	17	1.2
"	"	8.0	87	65	58	50	42	32	26	20	3.4
"	"	12.0	82	62	49	38	28	22	17	13	7.9
off screen current			100	100	99	98	97	95	91	90	2.5

Screen: (B). Percentage of number of fish-groups which broke through the electrified region of various depths to the total number.

Gold-fish.

Distance between electrodes in cm		Terminal voltage in volt	Period of intermission in sec.	Making-factor	Percentage of breaking through								
					1st electrode	The depth from the 1st electrode					2nd electrode	From the 2nd 20cm	3rd electrode
						20cm	40cm	60cm	80cm	100cm			
30	10	off screen current			93						86		80
"	"	3.0 continuous			76						49		31
"	"	" .09 $\frac{1}{16}$			84						34		20
60	20	off screen current			93						84		76
"	"	6.0 continuous			72						43		22
"	"	" .09 $\frac{1}{16}$			76						35		14
90	30	off screen current			95						88		85
"	"	9.0 continuous			79						31		15
"	"	" .09 $\frac{1}{16}$			76						22		11
120	40	off screen current			95	90	89	88	87	86	83	79	78
"	"	12.0 continuous			71	55	46	42	37	35	27	17	13
"	"	" .09 $\frac{1}{16}$			71	51	37	30	23	18	13	11	10
"	"	8.0 continuous			74	55	49	46	43	39	33	27	23
"	"	" .09 $\frac{1}{16}$			73	58	48	42	37	27	23	16	14

Carp.

Distance between electrodes in cm			Terminal voltage in volt	Period of intermission in sec.	Making-factor	Percentage of breaking through								
						1 st electrode	The depth from the 1 st electrode					2 nd electrode	From the 2 nd 20 ^{cm}	3 rd electrode
							20 ^{cm}	40 ^{cm}	60 ^{cm}	80 ^{cm}	100 ^{cm}			
1 st and 2 nd	2 nd and 3 rd													
120	40	12.0	continuous		87	72	66	59	56	55	42	31	25	
"	"	16.0	"		80	67	53	46	40	39	26	18	10	
"	"	12.0	.09 " $\frac{1}{16}$		80	73	62	53	47	43	38	31	25	
"	"	16.0	" "		81	66	52	44	40	35	30	23	18	
"	"		off screen current		100	98	98	98	98	98	93	93	91	

TABLE III.

Ratio of percentages of breaking through the electrified region of same depth of both cases where screen current was supplied and not. (%).

Gold-fish, screen : (A).

Period of intermission in sec.	Making-factor	Terminal voltage in volt	Depth of the electrified region in cm.							
			0	33	66	99	132	165	198	231
continuous		6.8	86	75	67	55	46	34	24	15
.57	$\frac{1}{4}$	"	96	88	76	64	57	51	47	44
"	"	"	96	90	79	65	61	53	50	53
continuous		"	88	78	63	48	41	33	23	18
.30	$\frac{1}{2}$	"	95	82	63	59	43	33	22	18
"	"	"	94	82	67	54	47	35	27	24
"	"	"	94	86	78	67	56	54	50	49
continuous		"	94	78	62	46	38	29	24	19
.15	$\frac{3}{4}$	"	94	78	58	42	29	20	15	15
"	"	"	91	75	53	31	19	14	10	10
"	"	"	97	88	76	61	52	46	36	32
"	$\frac{1}{8}$	"	96	88	76	61	51	43	38	38
continuous		"	93	78	63	49	39	30	19	14
.09	$\frac{1}{16}$	"	91	81	68	55	50	39	26	18
"	"	"	87	70	56	42	33	25	19	12
"	"	"	93	78	65	53	39	30	23	18
"	$\frac{1}{8}$	"	92	78	68	53	44	35	26	21
"	$\frac{1}{4}$	"	95	86	80	70	63	47	36	28
"	$\frac{1}{8}$	3.0	94	88	80	70	63	57	49	42
"	"	5.0	92	84	77	67	60	52	45	44
"	"	10.0	77	64	54	40	28	22	12	8
"	"	16.0	72	44	29	19	11	7	5	4

Carp, screen : (A).

Period of intermission in sec.	Making-factor	Terminal voltage in volt	Depth of the electrified region in cm.							
			0	33	66	99	132	165	198	231
.09	$\frac{1}{16}$	2.0	95	85	77	71	66	61	55	43
"	"	3.0	95	86	76	69	60	48	37	30
"	"	4.0	94	86	75	64	56	43	34	27
"	"	6.0	89	78	66	56	44	38	33	30
"	"	8.0	87	72	58	46	37	34	31	26
"	"	10.0	77	54	42	32	25	19	13	9
"	"	12.0	65	42	31	26	21	17	13	9
continuous		2.0	94	89	80	73	65	55	48	42
"	"	3.0	94	88	81	72	63	53	43	36
"	"	6.0	88	74	63	52	41	32	25	19
"	"	8.0	87	65	59	51	43	34	29	22
"	"	12.0	82	62	49	39	29	23	19	14

Gold-fish, screen : (B).

Distance between electrodes in cm		Terminal voltage in volt	Period of intermission in sec.	Making-factor	1st electrode	From the 1st electrode in cm					2nd electrode	From 2nd 20 cm	3rd electrode
						20	40	60	80	100			
30	10	3.0	continuous		82						57		39
"	"	"	.09	$\frac{1}{16}$	90						40		25
60	20	6.0	continuous		77						51		29
"	"	"	.09	$\frac{1}{16}$	82						41		18
90	30	9.0	continuous		83						35		18
"	"	"	.09	$\frac{1}{16}$	80						25		13
120	40	12.0	continuous		75	57	52	48	43	41	33	22	17
"	"	"	.09	$\frac{1}{16}$	75	52	42	34	26	21	16	14	13
"	"	8.0	continuous		78	61	55	52	50	45	40	34	30
"	"	"	.09	$\frac{1}{16}$	77	64	54	48	43	31	28	20	18

Carp, screen : (B).

Distance between electrodes in cm		Terminal voltage in volt	Period of intermission in sec.	Making-factor	1st electrode	From the 1st electrode in cm					2nd electrode	From 2nd 20 cm	3rd electrode
						20	40	60	80	100			
120	40	12.0	continuous		87	73	67	60	57	56	45	33	27
"	"	"	.09	$\frac{1}{16}$	80	75	63	54	48	44	41	33	27
"	"	16.0	continuous		80	68	54	47	41	40	28	19	11
"	"	"	.09	$\frac{1}{16}$	81	67	53	45	41	36	32	25	20

**Duration of Life and Rate of Reproduction of the Water-flea,
Moina macrocopa Strauss, with Special Reference
to Rate of Living.⁽¹⁾**

Arata TERAQ.

(Received March 15, 1932).

The well-established non-inheritance of the variations of the parthenogenetically reproducing individuals calls our attention to the degree of the interrelation of the variable characters of these specimens. If the variations of any two characters among a monoclonal population are correlated to a marked extent, it is reasonable to expect that these two would be significantly dependent, directly or inversely, upon each other for the maintenance of life of genetically uniform pattern.

The reasons to deal with the two characters, duration of life and rate of reproduction, of the water-flea in the present paper are two-fold. In the first place duration of life of *Moina* is a variable character, as already shown elsewhere. In the second place rate of reproduction of the cladoceran is also variable and may be regarded, according to Pearl's hypothesis⁽²⁾, as rate of living on which the length of life inversely depends. Computing the coefficient of correlaton of the two items in question from the data obtained by the late Mr. TANAKA and myself,⁽³⁾ we have

$$r_{12} = -.0835 \pm .0587$$

This result means that the two are not correlated at all with each other. But it should be noted that the rate of reproduction here discussed is an average number of offspring per day during the whole life and is not sufficiently accurate since the variable number of days required to begin parthenogenesis was not taken into consideration. The coefficient of partial correlation

(1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 26.

(2) Pearl, R. The rate of living, 1928. Alfred Knopf, New York.

(3) The cladocerans were kept at 27°C, one in each vial with food which was changed daily. The total number of the experimental animals was 130.

of the already mentioned items when the third factor is held constant is found to be

$$r_{12.3} = -.1836 \pm .0572$$

The degree of the correlation is again negligible. It should be admitted, however, that the experimental animals were kept under uniform environments but were not exposed to natural conditions. They were supplied from the mass culture which originated from a single mother and the date of the commencement of the experiment was not the same for all. It was clear that the later the experiment the less the vitality of the daphnids. Eliminating this factor, the partial correlation of the two characters in question is obtained to be

$$r_{12.34} = -.1467 \pm .0579$$

This result indicates that the net correlation between duration of life and rate of reproduction in the water-flea is insignificant. It follows therefore that a rate of reproduction is not always a rate of living on the ground of Pearl's theory. It is hoped that the present paper will contribute a small bit to further analysis of the problem.

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Ammonia Nitrogen	26	Hypodytes rubripinnis (Temminck & Schlegel) ..	9
Antennarius sanguifluus Jordan	12	Intermittent Current	55
Apogon lineatus Temminck & Schlegel	19	Inu ama Snyder	11
Apogon notatus (Hottuyn)	19	Luciogobius guttatus Gill	11
Apogon semilineatus T. & S.	19, 20*	Making-factor, of Electric Current	57
Aspasma minima (Döderlein)	12	Mapo poecilichthys (Jordan & Snyder)	9
Aspasma misakia Tanaka	13	McMillan's Screen	33
Bacteria	25	Melletes	4
Blennius yatabei Jordan & Snyder	12	Microcanthus strigatus (Cuvier & Valenciennes) ..	8
Buccal Incubation	19, 20*	Mugil cephalus Linné	7
Burkey	33	Muscle Protein	48
Calliodon ovifrons (Temminck & Schlegel) ..	18	Neohemilepidotus japonicus, n. sp.	4, 5*
Catherinus modestus (Günther) ..	15, 16*, 17*	Neohemilepidotus, n. g.	4
Carp	34	Ocynectes maschalis (Jordan & Starks)	9
Chaetomorpha Okamurai sp. nov. (Freshwater Species) (Pl. I)	23	Okada	33
Chasmichthys dolichognathus (Hilgendorf) ..	9	Ova	20*, 21
Chasmichthys gulosus (Guichenot)	9	Percoid Fish	19, 20*
Chelidodipterus quinquelineatus Cuvier	19	Petroscirtes elegans (Steindachner)	12
Clariger cosmurus Jordan & Snyder	9	Pseudoblennius cottoides (Richardson)	13
Clariger sirahamaensis, n. sp.	9, 10*	Psychrolutes	2
Coradion modestum (Temminck Schleger) ..	8	Pterogobius daimio Jordan & Snyder	13
Cottoid Fish	1	Rainbow Trout	34
Cottunculoides	2	Rate of Living	63
Cottunulus	2	Rate of Reproduction	63
Decomposition, of Fish Body	45	Rhinogobius campbelli (Jordan & Snyder)	9
Dictyosoma burgeri Van der Hoeven	12	Rhinogobius giurnus (Rutter)	9
Duration of Life	63	Rigidity, of Fish Body	45
Ebinania, n. g.	1	Safale taeniura (Cuvier & Valenciennes)	7
Ebinania vermiculata n. sp.	1, 2*	Salarias enoshimae (Jordan & Snyder)	12
Electric current	33	Scheminzy	33
Electric Fish Screen	33, 55	Scomber Flesh	25
Electrode	34	Sebastichthys elegans (Steindachner & Döder- lein)	12
Enneapterygius theostoma (Jordan & Snyder) ..	12	Sebastichthys mitsukurii (Cramer)	12
Epinephelus diacanthus (Cuvier & Valencien- nes)	12	Stethojulis terina Jordan & Snyder	8
Epinephelus moara (Temminck & Schlegel) ..	8	Terminal Voltage	36
Eurymen	2	Thallasoma cupido (Temminck & Schlegel) ..	8
Eviota abax (Jordan & Snyder)	9	Tide-Pool Fishes	7
Expedio parvulus Snyder	11	Tropical Fishes	7
File Fish	15, 16*, 17*	Voltage Gradient	36, 55
Fish Body	45	Water-flea	63
Fish Groups	33, 55	Xesurus scalprum (Cuvier & Valenciennes) ..	8
Gilbertina Jordan & Thompson	2	Zacalles bryope Jordan & Snyder	12
Girella punctata Gray	8	Zoarchias neglectus Tanaka	13
Gold Fish	34	Zoarchias veneficus Jordan & Snyder	13
Gonistius zonatus (Cuvier & Valenciennes) ..	12	Zonogobius boreus Snyder	9
		Zoospore (Pl. I)	23

